

September 6, 1973

## ACCELERATOR EXPERIMENT----Booster Injection Alignment II

Date Performed: 6, 8, 15 August, 1973

After having moved the junction of the septum and inflector in to get the inflector aligned parallel to the straightened closed orbit, a parallel move out was needed to enlarge the aperture. The present experiment includes this move of the inflector, a subsequent move of the downstream end of the orbit bump magnets, and an investigation of timing effects on the beam by pulsed devices.

Experiment

Before making a move of the septum-inflector, measurements were made of the closed orbit and injection beam angles. Tuning was done to straighten the closed orbit across injection and reduce the angle of the injected beam to the closed orbit. A curve was taken of the percentage of beam remaining at  $50\mu\text{s}$  in the injection toroid and at 3 ms in the charge detector as a function of orbump trigger time. One thus has the percentage survival as a function of orbit bump size.

After the above measurements and tuning were made both ends of the inflector were moved out 4 turns (5.08 mm). Wire 9 box was observed to move about .15 inches during the move; this measured 3.4 mm from beam center to beam center on wire 9 scanner before and after the move. The bellows on the last half of orbump was twisted by this move.

After retuning and measuring beam angles to insure proper injection, the same efficiency curve was taken again with a  $1\mu\text{s}$  beam as a function of orbump trigger time.

Because of an earlier observation during multiturn work that an 8-GeV beam increase from opening the chopper window earlier and later one at a time did not add up to the result of opening both ends at the same time a repeat of the experiment was done but this time looking at the charge monitor at approximately  $50\mu\text{s}$  after injection. Two tries of length increases of the chopper width of 1 and then  $2\mu\text{s}$  on either as opposed to both ends did in fact show the adding of charge. Unfortunately the rf was off so that the effect at 8-GeV could not be checked, but if the previous observation at 8-GeV of the non-addition of early and late beam in the chopper window is verified with no loss in coasting beam then it must be attributed to some intensity effect of the acceleration part of the cycle and not intensity loading of injection.

Before the efficiency data was taken, a wire 10 scan verified the essentially zero injection angle relative to the closed orbit by the phase of the betatron oscillations. Wire 10 scans were made with orbump triggered  $8\mu\text{s}$  earlier and  $5\mu\text{s}$  later. The earlier timed scan showed a negative injection angle and the later one a positive angle. This effect was attributed at the time to steering by S1 and S2, the pulsed devices. On re-examination of the data the effect of steering by S1 and S2 is not so clear if one has not changed the chopper time and thus the beam time relative to S1 and S2 time. However, due to the possible shift in relative time of pulsed injection devices from the normal 1 megaHz booster clock to the special devices on the 10 megaHz clock (a problem to be discussed later), it is still felt that the observed angle change was probably due to S1, S2 steering, a point to be checked at a later date.

Both S1 and S2 pulses were centered with respect to the beam. With the orbit bump time centered, the chopper time was opened to  $14\mu\text{s}$  and with a shift in tune the 8-GeV particle detector was saturated at  $.94 \times 10^{12}$ .

A first turn loss gave indications of being lost at or near the second half of orbit bump and a radiation survey showed the whole injection area to be hot. As a result of this, on August 7, the downstream orbump magnet was moved out to take the kink out of the bellows (.537 cm at the upstream end and .304 cm at the downstream end).

During beam time on August 8, multiturn tune up was done again and S1 - S2 pulses centered on the beam. A trick using the single-turn kicker at a very low level enabled a piece of one turn to be put in the middle of the orbit with essentially no betatron oscillation amplitude. This is shown in Figure 1 by two wire scans with the kicker on and off.

After this demonstration and some difficulty with a first turn loss, efficiency curves were taken again by moving the orbit bump trigger time. Three curves were taken using different chopper beam times (Centered,  $2\mu\text{s}$  early, and  $2\mu\text{s}$  later). Figure 2 shows efficiency curves taken before the parallel inflector move and after the inflector move. Later orbit bump trigger times mean larger amplitudes because one is on the falling side of the pulse. Larger amplitudes mean the orbit is pushed farther out and thus correspond to injection at smaller betatron amplitudes. From this graph alone, one might be encouraged to say that the parallel move of the inflector made a noticeable increase in the ability to inject small betatron oscillations and because of the increase in width of the curve a larger range as well. However, Figure 3 shows the curves taken after the orbit magnet was moved. Notice the two separate curves marked by an "X". When this data was being taken, a sudden shift in value was observed such that a recheck of earlier points produced the two similar curves that are shifted in time by  $2\mu\text{sec}$ . During many tuning periods, the time variation of beam current has shown shifts of this kind. During tuning to the edge of any beam acceptance on some device one would suddenly have beam intensity where previously there had been no beam. If one overlays the curves in Figure 2 and 3, the apparent gain seen in Figure 2 is covered by the  $2\mu\text{sec}$  shifted data in Figure 3. The amount of gain is not so clear under these circumstances. Besides an increase in small amplitudes would be expected from making the inflector parallel to the

beam (smaller septum thickness) and an increase in large amplitudes should be expected from a parallel move out (increased aperture).

The problem of time shifts had been related to the booster clocks. The normal 1 megaHz clock triggers most devices and is actually a variable frequency clock that has a feedback circuit to keep the number of clock pulses in a power line cycle constant within the average of several cycles. This is done to make a timing module trigger time constant with reference to the magnet cycle which is itself locked to the power line. A shift in power line frequency then shifts the booster clock which in turn shifts the whole world except for a couple of devices. The chopper and single turn kicker determine when the beam is in the injection line and they are triggered by a 10 megaHz crystal controlled clock. This clock is reset by the normal reset pulse but the frequency does not change. At injection time, the variation between the two clocks has been seen to be  $2\mu\text{s}$  and with power line frequency variations that are known to occur here several microsecond variation seems possible.

Figure 4 and 5 show two plots of beam position on the wire following S1 or S2 as the pulse time of that device is varied. Four turn injection requires a beam pulse length of  $11.2\mu\text{ sec}$  as shown by the bar in the graph. Pulse lengths of S1 and S2 must be classified as marginal for four turn injection. On August 15, this same problem was looked into in somewhat more detail. Figure 6 shows injection beam center position and injection angle as measured by wires 9 and 10 as a function of the trigger time of S1 and S2 moving together with S2,  $9\mu\text{ sec}$  later the S1. Figure 7 shows injection angle and wire 10 position as function of time. Figure 8 shows injection beam position as a function of the trigger time of S1.

### Conclusion

The septum-inflector alignment has been improved as exhibited by the increased record of intensity out of the booster. The efficiency data seem to indicate some improvements in the small amplitude betatron oscillation side of injection but are distorted by the clock timing problem. This problem is certainly more serious for multi turn work than single turn and will need to be solved.

The pulse lengths of the two pulsed septum devices S1 and S2 are adequate for one to two turns but only marginal for three and four. If an injection scheme of scraping many turns were wanted, the pulse lengths of S1 and S2 would certainly have to be lengthened.

E. Gray

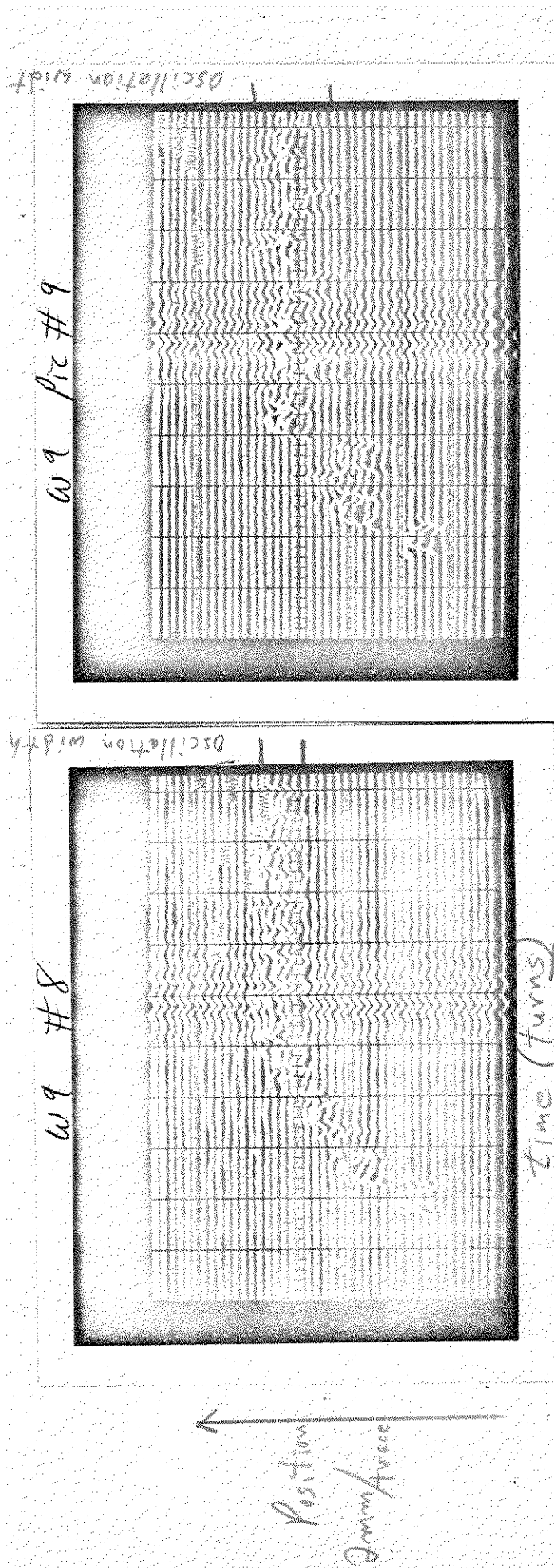


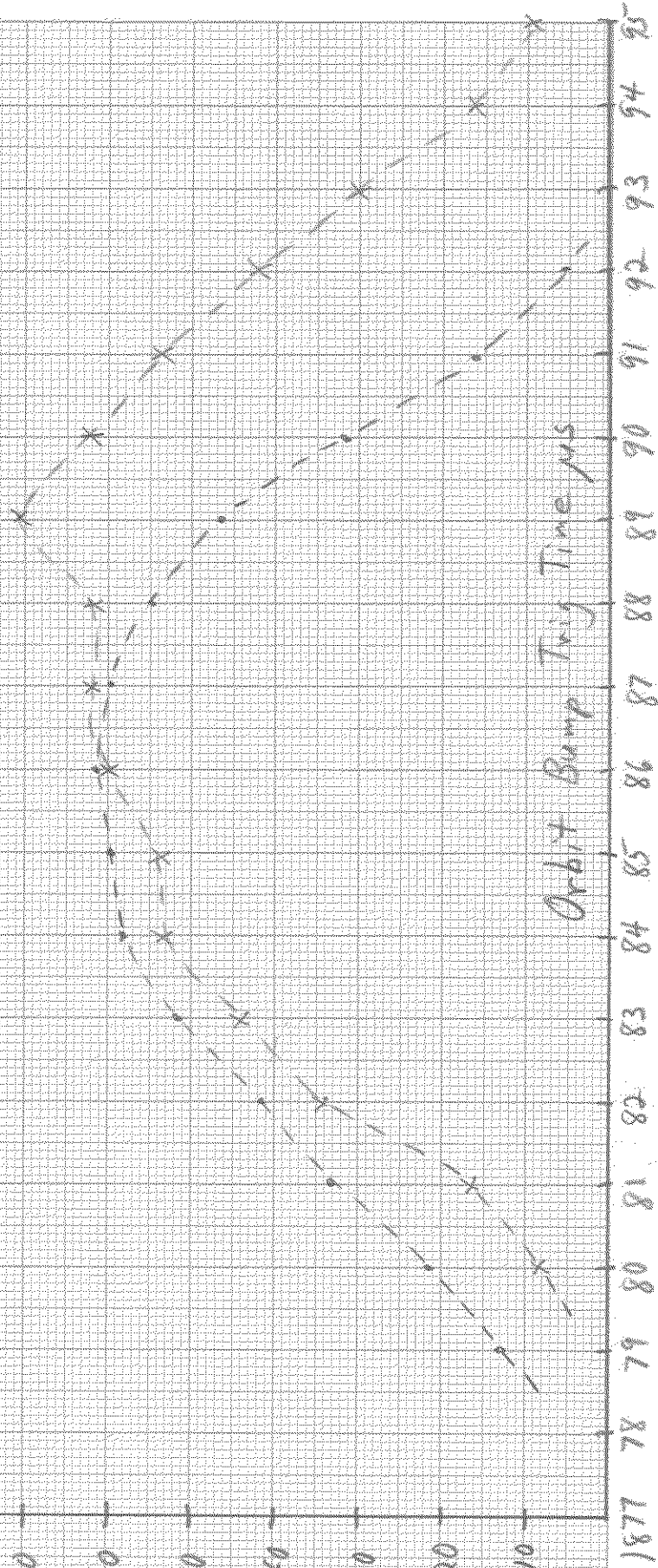
Figure 1

% Beam Survival  
I<sub>0</sub>/50ps I

Before Int Move 30ps for  
X After Int Move 50ps for

Trigger Times  
51 1854 50 1864

Figure 2



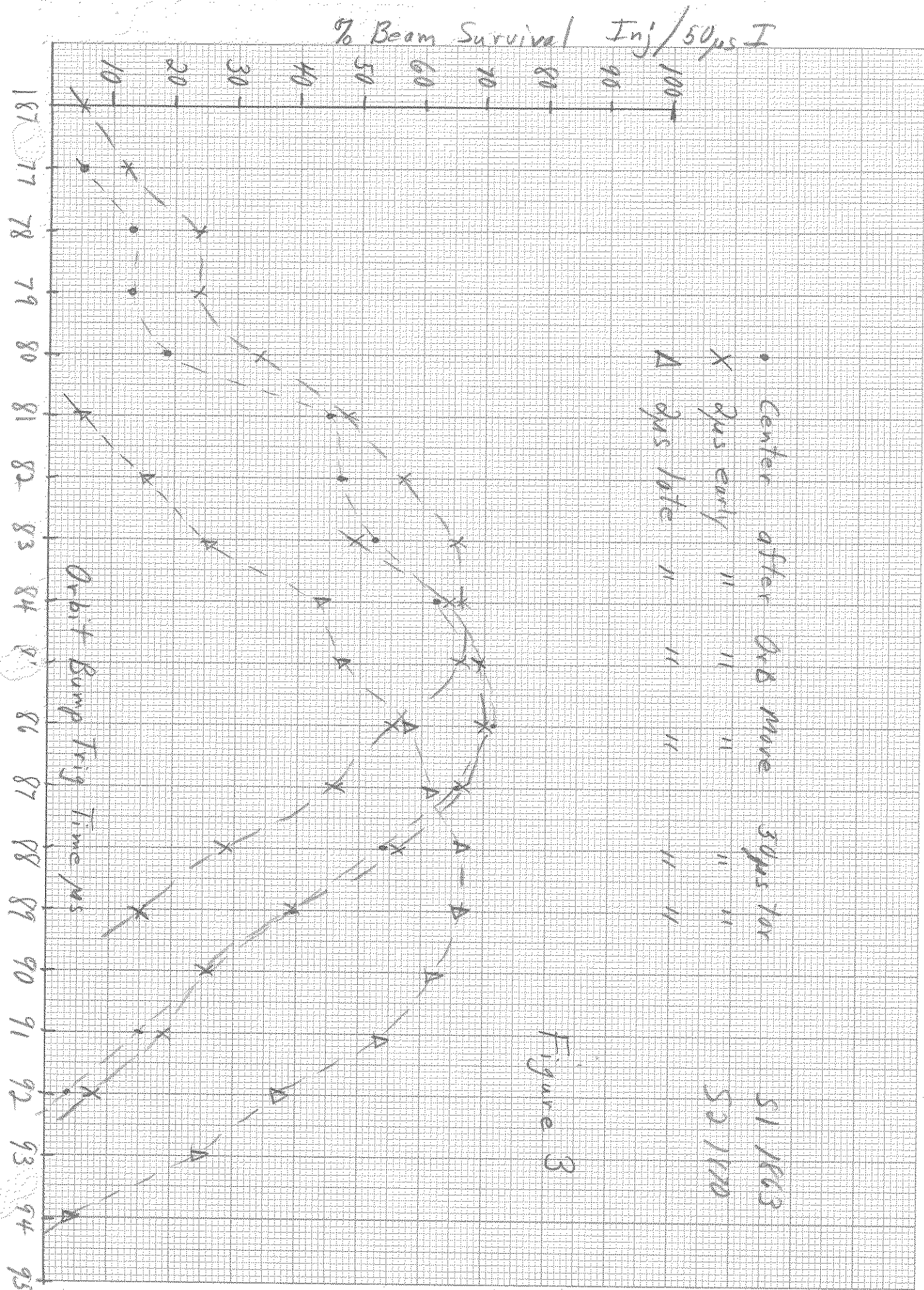
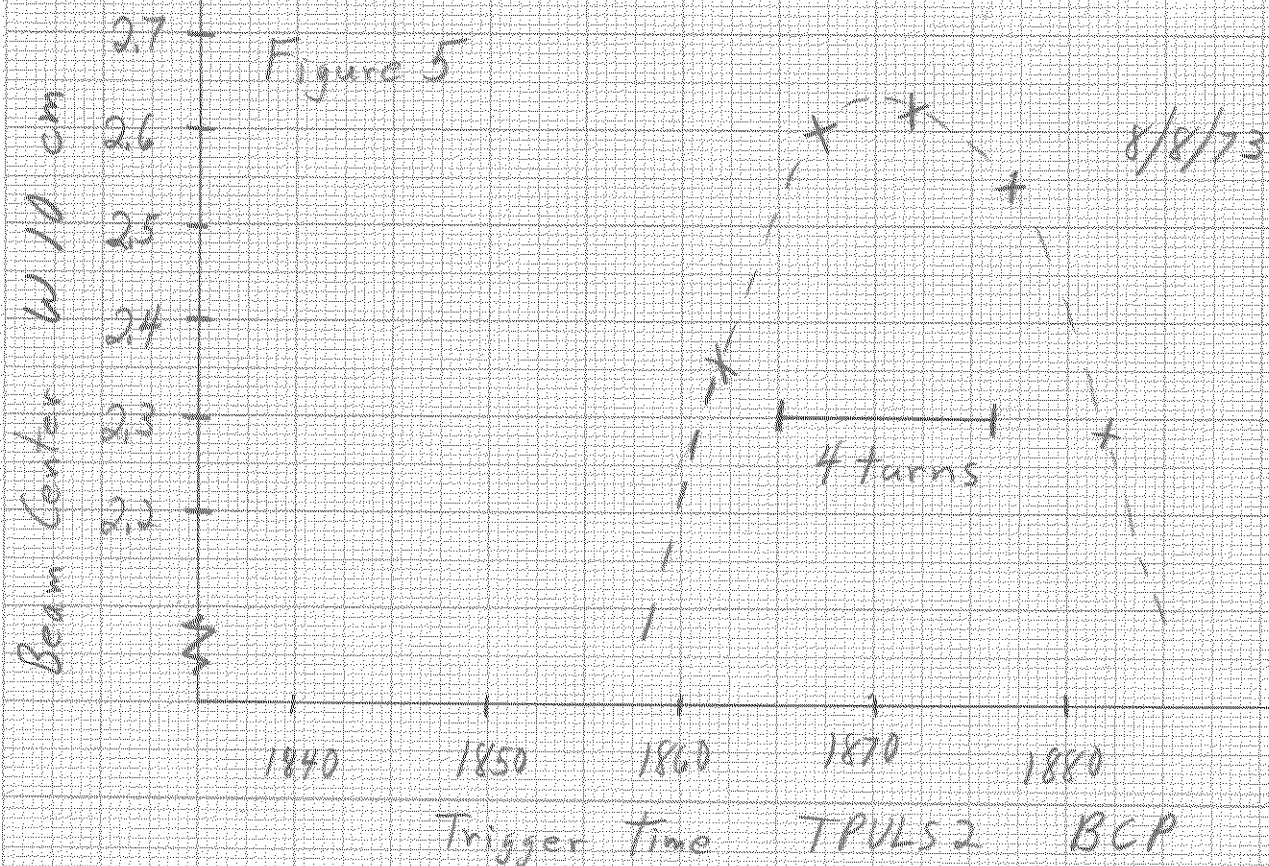
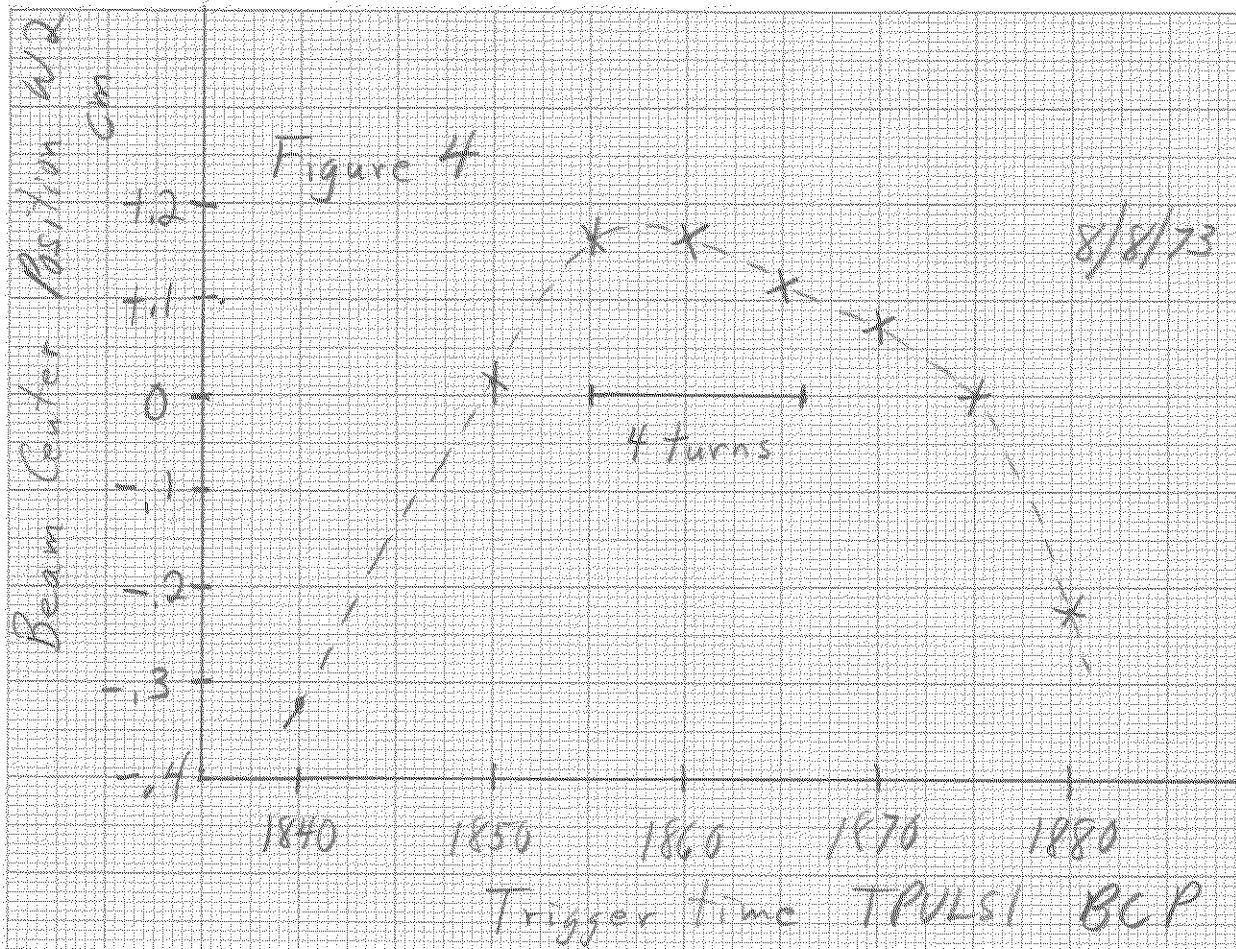
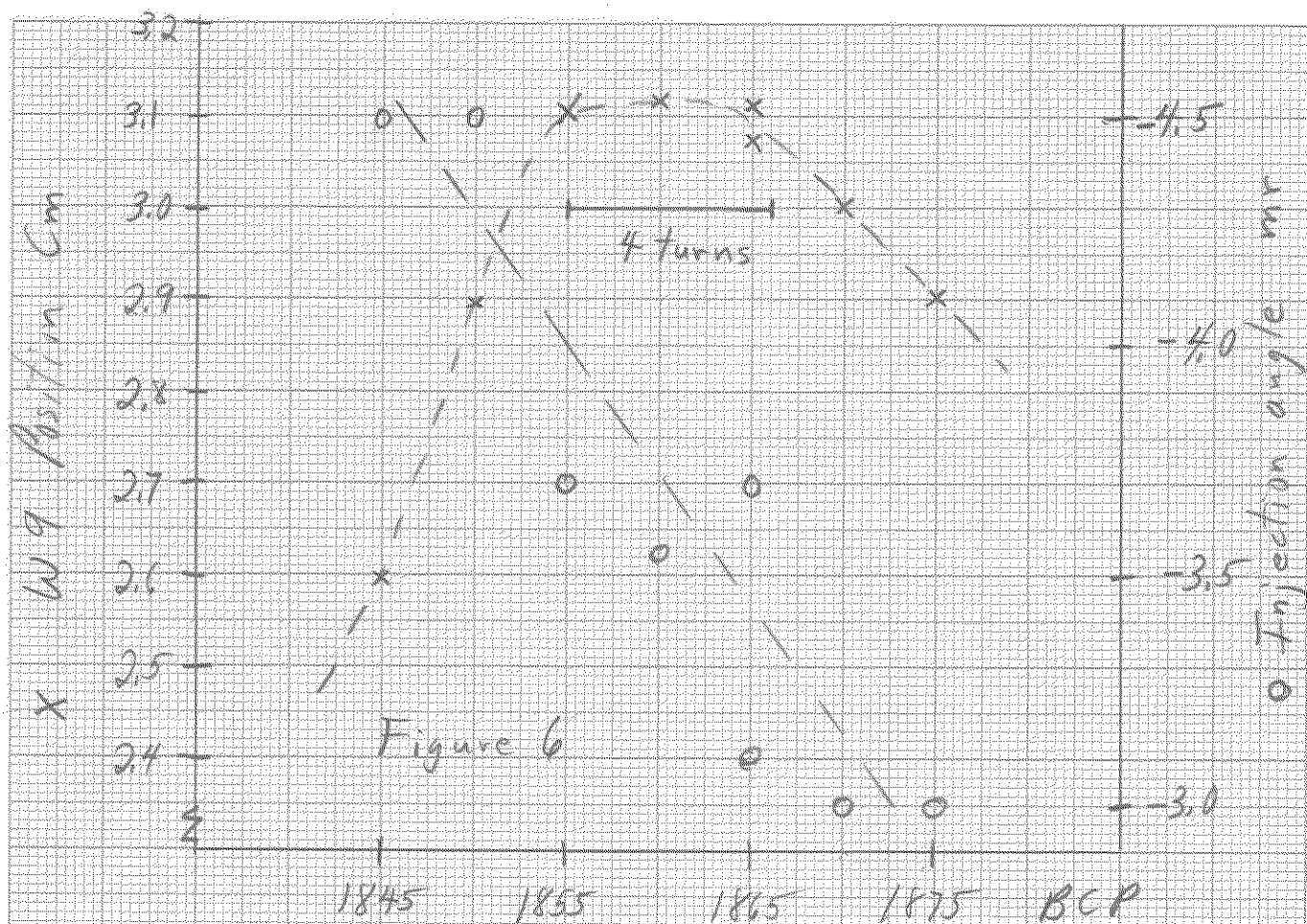
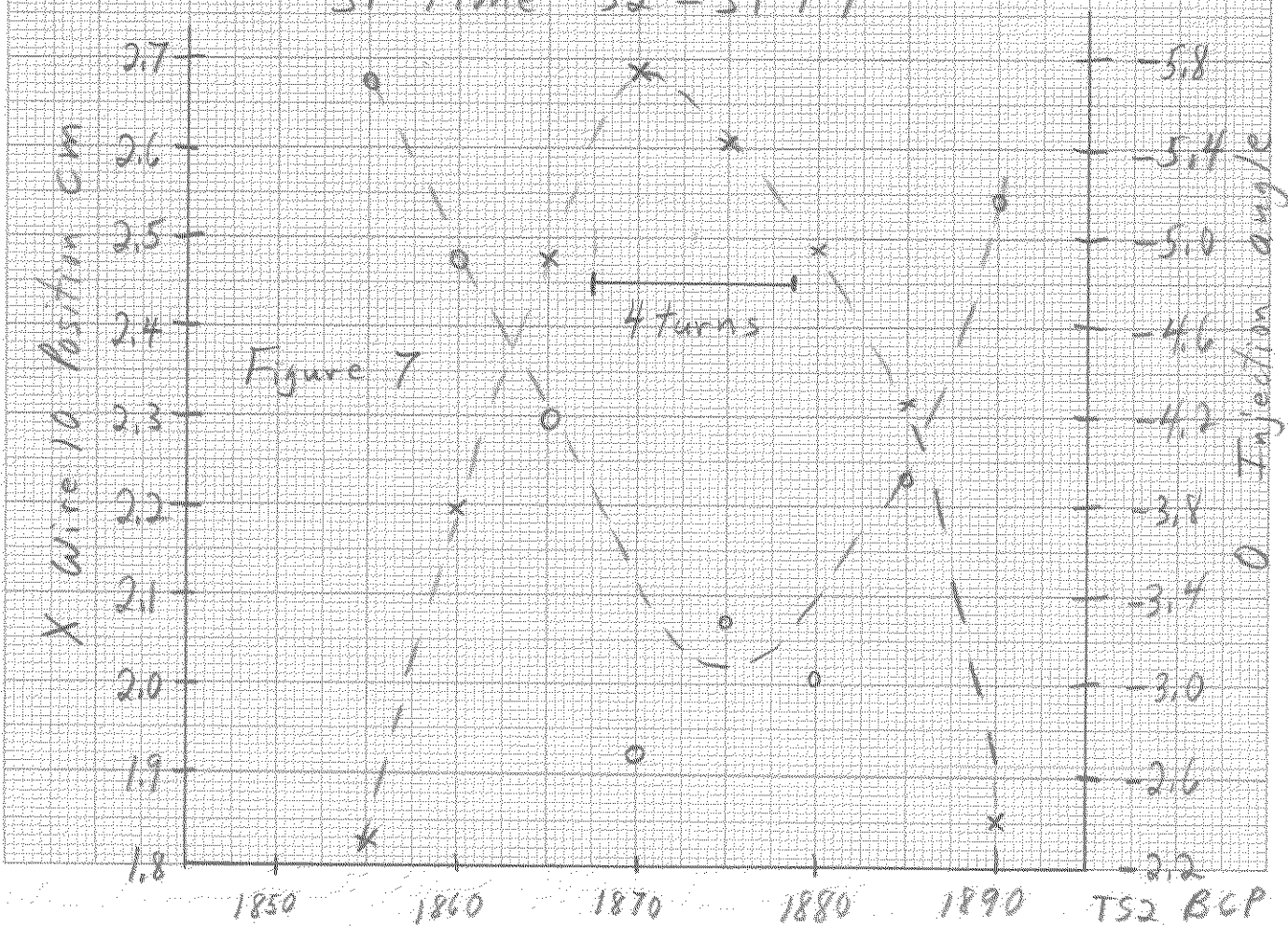


Figure 3





$S1 \text{ time } S2 = S1 + 9$



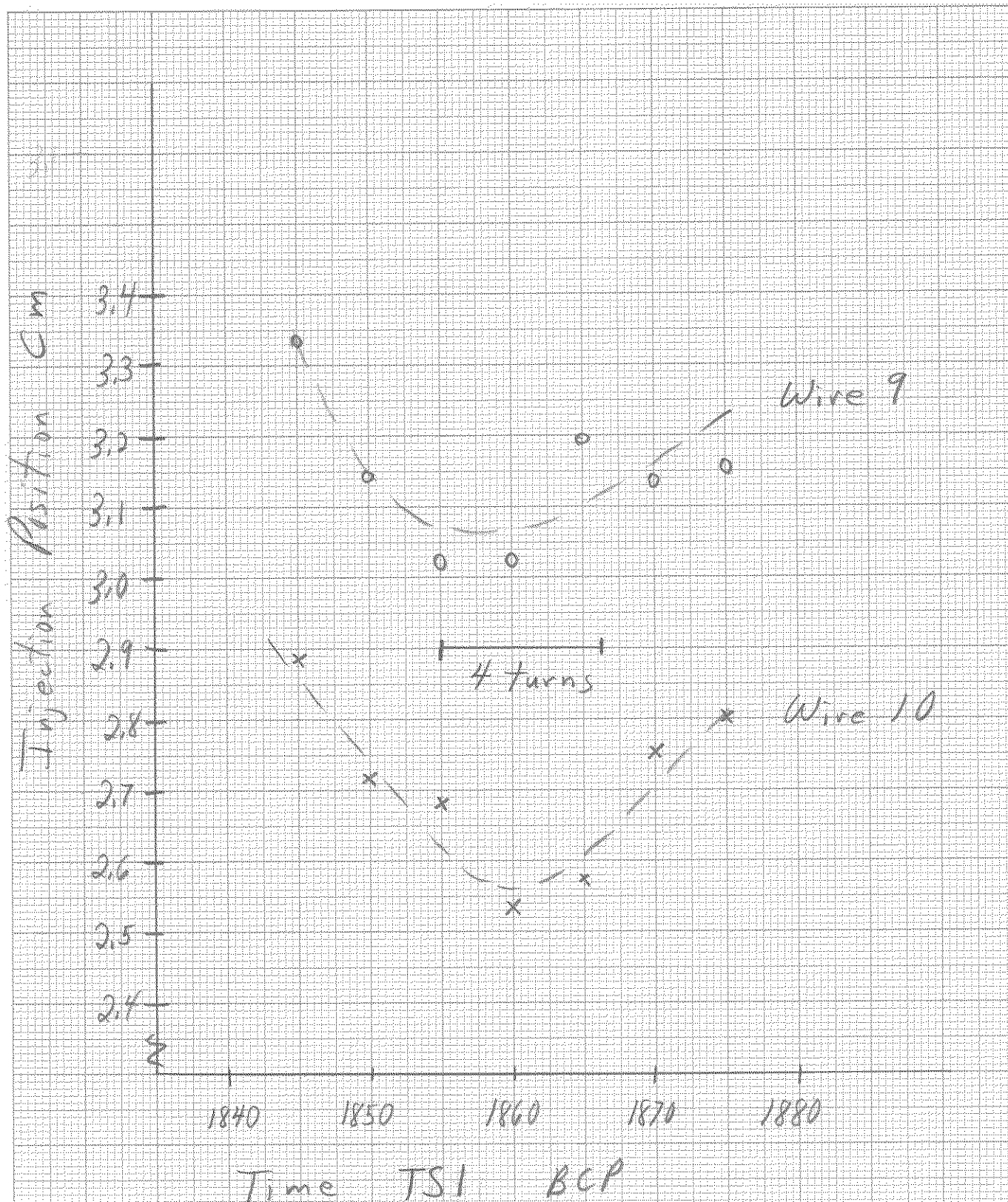


Figure 8